ENCLOSURE 2

Non-Proprietary Version of BWROG ECCS Suction Strainers Benchtop Test #2 (BT2) Fuel Rod Surface Effects Test Plan, R0 [1140BWRBT-302-01-NP]

BT2 – Fuel Rod Surface Effects Test Plan – Revision 01

Non-Proprietary Version

1140BWRBT-302-01-NP

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INFORMATION NOTICE

This is a non-proprietary version of the BT2-Fuel Rod Surface Effects Test Plan, which has proprietary information removed. Portions of the document that have been removed are indicated with space inside open and closed brackets as shown here [[ ]].

Record of Revisions

Revision No.	Revision Date	Change Description	Reason for Change
00	9/25/2014	Initial issue	
01	09/26/2014	Replaced "Redacted version" with "Non-proprietary version" on title page	Client request
		Added "Information Notice" to page ii	Client request
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1.0 Objectives

Alden has been working with Anatech / Structural Integrity for the BWROG to execute a full height fuel bundle test program [1] aimed at validating that the effects of debris blockage assumed in a bounding analysis for the fleet of BWRs [2]. The conditions of these tests have been reviewed by NRC staff and several rounds of Requests for Additional Information (RAIs) have been received [3][4]. A benchtop test program has been devised (Attachment A in [4]) to evaluate staff concerns using a set of simpler, more economical tests. The tests are aimed at demonstrating that the currently planned full scale test program will be sufficient to show that the bounding analysis is indeed conservative for all relevant plant conditions.

The objective of benchtop test 2 (BT2), in particular, is to determine whether the surface conditions on the fuel rod have an impact on the following:

1) Debris bed formation at the spacer grid
2) Resilience of the debris bed to counter-current steam flow

2.0 Approach & Basis

The approach to BT2 has been previously reported in Attachment A [4] and is repeated here. BT2 will evaluate debris bed formation on a single spacer grid equipped with short fuel rod stubs. The surface of the fuel rod stubs will be modified from new / smooth fuel rod conditions to evaluate if debris bed formation is affected by these changes. In addition, once the debris bed is formed, selected tests will examine the persistence of the debris bed in the presence of counter-flow air injection below the spacer grid to simulate counter-current steam flow.

Counter-current steam flow is likely in the early part of the cool down process where the fuel rods still supply sufficient heat to cause boiling within the fuel bundle. In addition, should significant blockage occur, the single-phase condition with established debris beds may revert to steaming. For these conditions, it is important to establish that the blockage will be removed by moving back to a boiling environment. It is therefore important to investigate a range of counter-current steam flow conditions to evaluate whether a minimum counter-flow strength is required to effectively clear the spacer grid blockage.

The modification of the fuel rod stubs will simulate the surface conditions of older fuel rods that may have surface scale or other deposits. Since it is difficult to quantify the potential roughness and scale thickness of an aged fuel rod, a range of conditions will be evaluated with the expectation that engineering judgment can be used to verify that surface conditions do not affect debris bed formation or debris bed resilience to counter-current steam flow.

A range of flow and debris conditions will be evaluated for BT2 to bracket the expected conditions at the fuel bundle spacer grid. Flow will be from above to simulate conditions for the full height bundle Test 4 [1]. The flow rates will be varied since the down-flow through the spacer grid will depend on the amount of cooling occurring at each time step in the accident progression. The upper limit will be determined from peak cooling requirements and the low flow limit will be determined during the course of the testing depending on the sensitivity of the results to flow rate.

A single spacer grid is sufficient for these tests since spacer grid to spacer grid interaction is unlikely given the small scale of flow structures (on the order of the fuel rod pitch, ~[[ ]][1][5] relative to the spacer grid to spacer grid distance which is generally between 1.5 and 2 feet [1][5]. A fully-rodded spacer grid will be employed in the tests since these spacer grids are most likely to form a debris bed and are therefore most likely to be sensitive to the fuel rod surface conditions. The flow condition limits will be representative of a fully rodded spacer grid. The highest flow conditions are appropriate for upper partially rodded spacer grids since the required downward cooling flow is greatest at that location and the steam flow attempting to escape is greatest at that location as well. The fully rodded spacer grid test conditions in BT2 must represent possible expected flow conditions for these spacer grids, both in terms of cool downward water flow as well as simulated steam up-flow.

The debris conditions will be varied within the parameter space of plant conditions evaluating whether or not fuel rod surface effects depend on debris bed composition or quantity. Debris quantities will be chosen to be sufficient to cause blockage that could impede cooling. The debris make-up will be divided into two groups: fiber and particulate. While various subtypes may exist the phenomena under investigation here are not likely to be sensitive to these selections. Fibrous debris will be represented using Nukon insulation. Particulate debris will be represented by a constant mixture dominated by iron oxide (representing sludge) but also containing jet pulverized acrylic paint chips (representing fine coatings particulate). The mixture of iron oxide and coating particulate will remain constant at a value that is representative of the fleet.

In order to be able to investigate the above effects on debris bed development, diagnostics that characterize the debris bed must be implemented. The diagnostics must consider both the permeability of the debris bed as well as its resilience to removal or modification by counter-current steam flow, represented with airflow.

Characterization of the debris bed development can also be accomplished by measuring the amount of debris that is retained at the spacer grid.

2.1 Assumption

a) Unqualified coatings outside the ZOI will fail as debris similar in form and behavior to coatings located within the ZOI and therefore their contribution or effects is incorporated in the present test program since the present test program incorporates ZOI coatings debris. This assumption is justified looking at NEI 04/07 and the statements of unqualified coating failure (p.3-30, [14]).

b) **Unverified:** The ZOI coatings contribution to particulate loading is bounded by 85 lbm. This assumption is based on the NRC submittals that will be expanded upon in the contents of BWROG-ECCS-TP-8-3, "Coatings ZOI" [12].

3.0 Experimental Setup

A sketch of the experimental setup is provided in Figure 3-1. The experimental setup is divided into four areas. The debris introduction section manages the inflow of clean water and addition of appropriately diluted debris. The inlet section will be designed to allow flow velocity profile effects generated by the debris introduction section to dissipate prior to arrival at the spacer grid. The spacer grid section will guide the flow through the spacer grid and the installed fuel rod stubs. Below the spacer grid section, an air introduction assembly will be designed to provide uniformly distributed air up-flow simulating counter-current steam flow. The outlet flow region will be designed to provide a constant flow rate and filter out debris that was able to move through the spacer grid. The clean flow is returned to the debris introduction section to provide for closed loop operation but a three-way valve is provided that allows for the possibility of aligning the flow back to the water reservoir. Each branch line is equipped with a balance throttle valve so that flow can be switched seamlessly without requiring a separate flow adjustment. A pump bypass loop is provided since the test loop flow rates will be relatively low (see Section 4.1).

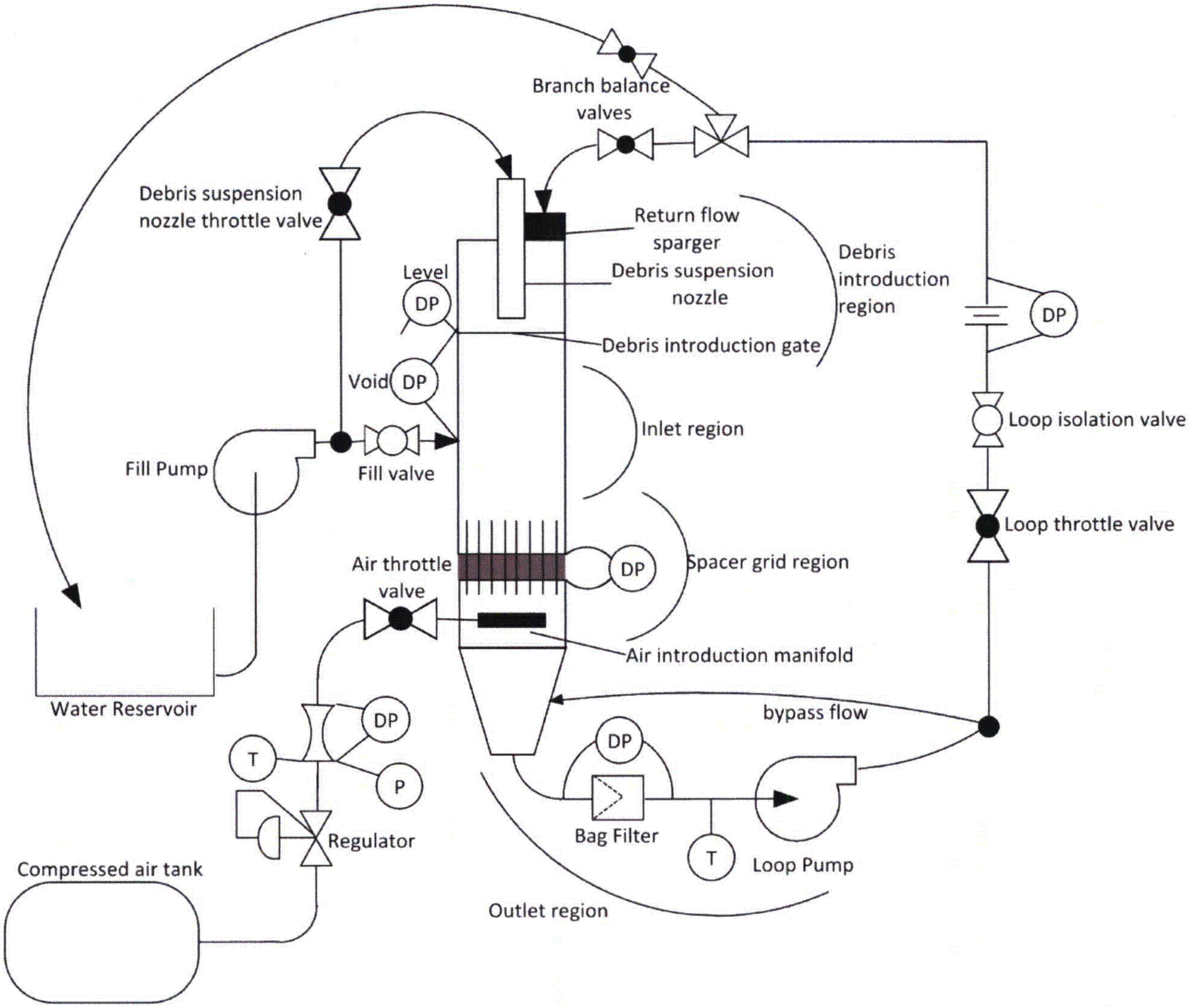

Figure 3-1. Experimental Setup Schematic

3.1 Debris Introduction

The debris introduction region includes the water reservoir and fill pump. The critical aspects of the debris introduction system are as follows:

- Debris added to the loop must not transport to the inlet and spacer grid regions immediately upon introduction.
- The added debris must be kept suspended after addition to the loop.
- The debris introduction system must be designed to minimize debris retention.
- The start of debris flow towards the inlet and spacer grid regions must be able to be coordinated with the start of loop flow.
- The debris introduction region must be large enough to accommodate at least 25% of the prepared debris quantity at the range of debris concentrations to be considered (see Section 4.3.3). The debris introduction region must therefore be able to hold more than 5 gallons of prepared debris mixture.
- The components for the debris introduction region must be able to withstand temperatures up to boiling.

Figure 3-2 illustrates a possible manner in which some of the critical requirements listed can be met. Using a wafer double door check valve (also shown in Figure 3-3), the fill pump maintains a sufficient pressure drop to cause the check-valve to remain closed. At the same time, a small amount of flow is added into the volume above the check valve to maintain the debris slurry in suspension until the test is ready to begin.

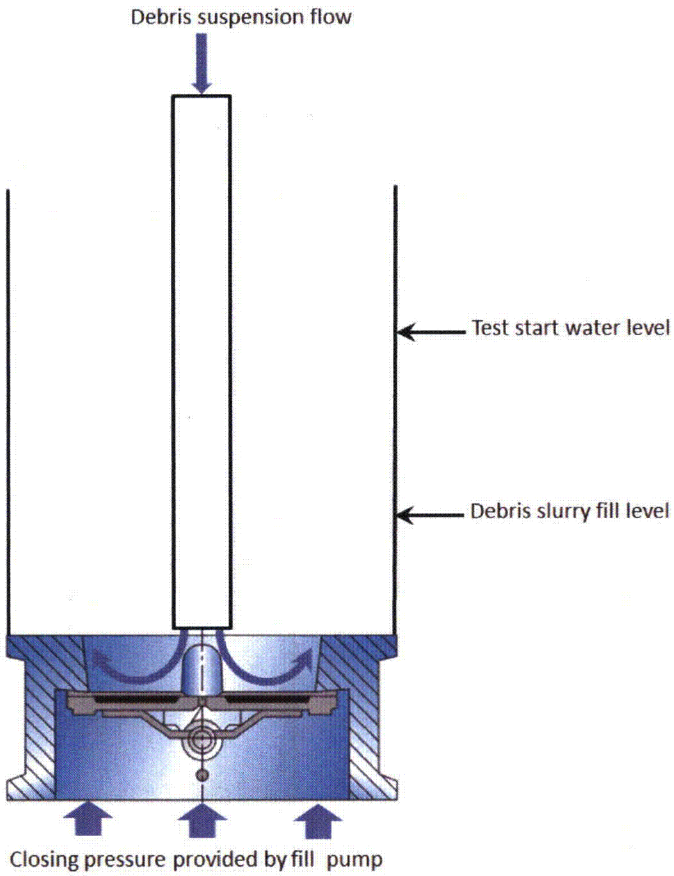

Figure 3-2. Debris introduction section

Figure 3-3. Wafer check valve debris flow inlet control

The double door check valve allows a very large flow area to develop when the valve opens once the test has started (and the fill pump flow has been secured). The hinges of the check valve are protected from direct flow exposure, reducing possible debris retention. The springs attached on the check valve doors at the hinges can be altered or removed to ensure the valves open fully when the test starts.

The internal diameter of the fuel channel is 5.278 in [5] with corner radii of 0.45 in [5]. The equivalent internal area of the fuel channel for a pipe can be calculated to be 5.02 in. Due to the obstruction of the check valve or other debris slurry separation device, the design of the debris introduction section will employ a pipe size at or above 5 inches.

As discussed below in Section 4.3.3, the capacity of the debris introduction region may not be sufficient to hold the entire volume of prepared debris slurry. Under these circumstances, debris suspension in the debris introduction region is maintained through manual stirring while additional debris slurry is added to the region to maintain the water level. The loop return flow is discharged to the water reservoir under these conditions until all of the debris slurry has been added.

3.2 Inlet Region

The inlet region must adapt the debris introduction region outlet to an appropriate square channel. The square channel will have internal dimensions that are smaller than the fuel channel and the width of the spacer grid. The objectives of the test do not include the simulation of the flow through the clearance between the fuel channel and the spacer grid. The square channel will therefore be designed with an internal width of 5.0625in (+/- 0.0625). If adaption from a round cross-section to a square cross-section is necessary, the adaption of the round debris introduction region to the square channel will occur by first transitioning to a square channel that encompasses the round pipe and then gradually contracts to the target internal width of 5.0625in. The contraction angle should not be more rapid than 20 degrees. Shallow contractions prevent non-uniform flow at the boundaries and ensure surfaces that have little possibility of debris accumulation, even at low velocities.

Once contracted, the channel flow velocity profile will be allowed to develop over a distance of 15 in to 18 in. The development length is sufficient to obtain an approximately even velocity profile across the channel that exhibits little evidence of the debris introduction region wakes. The contraction and debris introduction hardware contributing to the initially non-uniform flow must therefore have at least one characteristic dimension of less than two inches for the plane perpendicular to the flow direction. For example, the bar protecting the door hinges on the double door check valve (assuming the check valve is selected for use in the debris introduction region) must have a width of less than 2 in. The other dimension perpendicular to the flow direction in this case is quite long, spanning the entire internal diameter.

3.3 Spacer Grid Installation

The spacer grid installation includes the stub fuel rods. To be able to investigate debris accumulation patterns under the various conditions of BT2, the entire spacer grid assembly with stub fuel rods installed must be able to be removed from the set-up. Disturbance of any debris bed that may have formed will need to be minimized. The fuel rod stub length should be sufficient to allow fully developed flow by the time the flow reaches the spacer grid surface. Considering the pattern of fuel rod arrangement and the dimensions given in Reference [5], the characteristic dimension of the channel of water between fuel rods is approximately [[ ]] (D_{frc}). To allow adequate flow development, the fuel rod stub length above the spacer grid should therefore be at least [[ ]]. To aid in the development of the flow field between the fuel rods, the tips of the fuel rods should be equipped with a conical or bullet-shaped cap. The cap has the role of accelerating the flow into the fuel rod stub region smoothly and preventing debris from being caught at the fuel rod stub tip. The tip length extends upward from the minimum straight length requirement of [[ ]].

Below the spacer grid, the upstream influence of the flow disturbance caused by the termination of the fuel rod stub must be kept away from the spacer grid surface. The upstream flow disturbance at the fuel rod stub termination is expected to affect less than $2D_{frc}$ ([[ ]]) of the channel upstream, and likely much less. The minimum fuel rod stub length below the spacer grid will therefore be set to [[ ]].

The fuel rod stubs, which are likely to be hollow, must not allow flow through them and any air that may remain in the fuel rod stub must not be released during testing. It is sufficient to verify these requirements visually at the start of testing using dye flow visualization.

Fuel rod stubs will be prepared with various surface characteristics (see Section 4.4). To ensure the surface characteristics are not altered at the interface between the spacer grid top and bottom surface, the roughened fuel rod stubs will be made in two parts. The top of the fuel rod stub is inserted from the top and the bottom of the fuel rod stub is inserted from the bottom. By constructing the fuel rod stubs in two parts, any modification of the surface characteristics through insertion is minimized and the characteristics at the top and bottom surfaces of the spacer grid will be unaltered from their pre-test characterization. The connection method between the two parts of the fuel rod stub has to meet the requirements cited above that prevent flow through the fuel rod stub and prevent air from being released from the fuel rod stub.

The spacer grid represents the only strictly prototypical component used in BT2. In order to verify that the condition of the spacer grid remains in satisfactory condition, the following will be performed before the first test and after all conducted tests:

- Selected fuel rod passages are photographed in a clean condition to document the general condition of the spacer grid.
- The fit of a clean fuel rod stub is checked in each fuel rod hole. The check will be performed by ensuring that the spacer grid is able to maintain all three radial points of contact in each fuel rod location.
- The overall square dimensions will be measured and compared to past measurements and the required dimensions [7].

A fully rodded spacer grid is chosen for BT2 to increase the likelihood of bed formation and thereby increase the sensitivity to fuel rod surface conditions.

To limit the potential for damage to the spacer grid, the installation of fuel rod stubs will only use axial motion and prevent twisting. Twisting could damage the springs more easily and could cause increased damage to the fuel rod stub surface characteristics in the installation process.

All spacer grids have water rods. The water rod has different diameters depending on the location of the spacer grid. In the region of limiting flow conditions in the mid-section of the fuel bundle, the water rod diameter is at a maximum, [[ ]] [5]. The surface of the water rod will not be modified along with the fuel rod stub surfaces. The surface will remain clean. Since the flow passages adjacent to the water rod are no larger than the typical flow passages between fuel rods, the stub length for the water rod is also not required to be larger. Similar to the prototypical situation, the water rods will be locked in place vertically using tabs. To improve the security of the installation a slightly smaller distance will be implemented on the water rod stubs. The typical distance between tabs is [[ ]] [8] to hold a spacer grid that is nominally [[ ]] [7] thick. The distance between the two tabs on the water rod stubs will be sufficient to prevent the water rod from moving freely during flow testing. To eliminate any flow bias to the region near the water rods that may occur if the water rod stubs were left at the same length as the fuel rod stubs, the water rod stubs will have twice the length of the fuel rod stubs both in the upstream and downstream directions. The water rod stubs will therefore extend [[ ]] upstream and [[ ]] downstream of the spacer grid. Similar to the fuel rod stubs, the top of the water rod stubs will be equipped with a conical or bullet shaped tip to prevent the collection of debris in these areas. While some flow through the water rods may be prototypical depending on the hydraulic conditions, the objectives of the present test can be achieved most easily if flow through the water rods is prevented.

During testing, the dominant flow path must be through the spacer grid and not through any clearances that may exist between the spacer grid and the surrounding flow channel. Flow visualization near the edge of the spacer grid can be used to verify that flow through the clearances around the spacer grid is small. Flow visualization must show the absence of flow acceleration into the clearance.

To facilitate meeting the above two flow field requirements, dye injection ports should be provided near the spacer grid surface and within the clearances around the spacer grid. In addition, a fuel rod and water rod stub can be filled with dye during selected tests to verify that the construction method satisfies the requirement for not allowing flow through the fuel rod stubs or water rod stubs.

3.4 Air Introduction

The air introduction manifold will be mounted below the spacer grid installation section. Some test conditions will exhibit relatively high void fractions. The following paragraphs describe the critical requirements for air introduction in BT2.

When the air arrives at the bottom of the spacer grid, a relatively uniform cross-sectional distribution of air is targeted. Slug flow with a predominant amount of air in the center is to be avoided to the extent possible using the air injection method.

Air injection must not occur directly in the counter current direction to prevent such non-prototypical momentum from interfering with the intended prototypical debris bed evolution when counter-current steam is present.

The flow obstruction caused by the air injection manifold should be minimized. If the injection manifold interferes with flow below the spacer grid installation, the air injection manifold must be able to be removed after the test to allow any debris collected on the manifold to be documented and measured.

Air flow uniformity at the spacer grid is to be documented using video taken from all sides of the test at a location just below the spacer grid. The final air injection arrangement will be documented in the facility inspection and the achievement of uniform air flow introduction will be documented using video.

To prevent air transport in the downstream direction, a continued constant cross-section is to be provided below the air introduction section. The height of this section must be at least 6 in to prevent the contraction in the flow outlet from interfering with air injection and possibly causing air entrainment in a downward direction. Air entrainment in a downward direction is not prototypical for the blocked lower tie plate conditions simulated during the full height bundle Test 4 [2].

Radial air injection from an array of various sized nozzles is one approach to air introduction that avoids debris retention concerns and should be able to meet the above uniformity requirements. Air in this case would also not have any artificial vertical component. The sizing, number and arrangement of the nozzles can be developed in shakedown testing. The arrangement of the nozzles and their sizes may need to shift with the target air flow introduction conditions. In all cases the downward velocity of the water is expected to be small enough to not significantly affect air flow distribution from one water flow rate condition to another.

It is possible that blockage conditions could be reached that do not allow all air to flow upward through the spacer grid; the accumulating air would result in an immediate increase in the differential pressure across the spacer grid. At the same time, additional water will pour into the top of the BT2 debris introduction region further increasing the water column height above the air blanket and the differential pressure across the spacer grid. These consequences of air / steam accumulation below the spacer grid are prototypical.

3.5 Flow outlet

The role of the flow outlet is to connect the lower end of the BT2 test stand to the remainder of the recirculation loop. The test stand flow velocities are relatively low based on the range of flow rates that will be tested (Section 4.1). In order to prevent settling in non-vertical sections and maintain reasonable pump operating points, a pump bypass loop will be used. The pump bypass loop increases the cross-sectional velocity in the test cross-section below the air introduction. A minimum of 10 gpm will be provided by the pump bypass loop, thereby allowing a piping connection with a 2 in diameter to provide velocities above 0.5 ft/sec, ensuring full transport of any debris that has passed by the spacer grid. The contraction to 2 in will be accomplished in a gradual fashion with a contraction angle not exceeding 20 degrees.

The addition of the bypass flow to the test loop flow must be done carefully. Installation of an internal bypass flow header could cause debris hold-up on the header which would need to be documented and measured. Direct radial inflow of the bypass flow is not recommended since this would likely cause flow disturbances above the introduction location and therefore increase the required straight flow path length below the air introduction. One possible approach for bypass flow addition is the distributed introduction of the bypass flow along a given height through perforated plate, as illustrated in Figure 3-4. A bypass flow addition height of 12 in will provide a velocity of approximately 0.05 ft/sec through a perforated screen with 25% open area.

The outlined bypass flow introduction method is an example. The critical requirement for the bypass flow introduction is that the test loop flow is not affected at the location of air introduction or above.

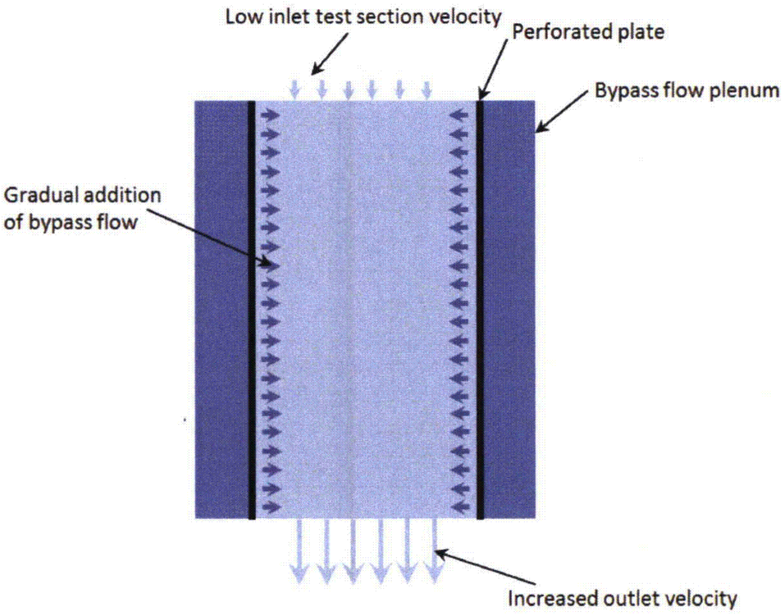

Figure 3-4. Outlet section bypass flow addition

Once flow has been contracted to a 2 in pipe, connection to a filter bag assembly on the suction side of the pump can be accomplished in a relatively straightforward manner. Downstream of the pump, the test flow return flow rate must be measured and controlled using a throttle valve.

The pump speed will not be adjusted after test start. The slow variation of flow that may occur during the test due to the filter bag and spacer grid pressure drop will aid in the interpretation of the test results and may provide a more sensitive measurement of debris bed evolution than simple differential pressure measurements. If the flow rate varies by more than 10% a pump speed or throttle valve adjustment will be implemented. The debris that passes through the spacer grid will be quantified by tracking the weight gain of the installed filter bag.

In cases where the debris slurry volume exceeds the capacity of the debris introduction region (see Section 3.1 and 4.3.3), realignment of the pump discharge will occur during the test. In order to smoothly switch from discharge to the water reservoir to recirculation to the debris introduction region, the resistances of these two paths must be able to be balanced. A three-way valve is recommended to accomplish the switch.

4.0 Experimental Conditions

4.1 Water Flow Conditions

BT2 is focused on submerged bundle testing, and will therefore inherit the flow rate test range for the submerged water full height bundle tests. The flow rates for these conditions are specified as between [[ ]] [1][6], converting the given mass-flow rate of [[ ]] [6] to a volumetric flow rate using the water density at boiling water conditions (atmospheric pressure).

Water chemistry is not expected to play a role in the mechanism being investigated with BT2. Whether or not fuel rod surface characteristics play a role in the debris bed development and resiliency is not expected to be a function of water chemistry. Plain tap water will therefore be utilized in testing. Water quality will be tracked by measuring the pH at the start of testing.

The water temperature will be maintained constant during testing. The influence of fuel rod surface conditions is not expected to be a function of fluid temperature. In general lower temperatures will generate higher head-loss. Therefore, lower temperatures, may allow more sensitive measurements. To ensure the water temperature can be repeated under a variety of conditions for the surroundings, a temperature of 80°F is selected as the constant temperature for testing. Ensuring the tests are maintained within 5°F of this target will allow any possible temperature effects to be controlled. In order to prevent pump energy addition from causing an excessive temperature rise during longer term recirculation (should termination criteria not be met quickly, Section 8.1), the recirculation path can be switched temporarily back to the water tank, while level is maintained in the debris introduction region using cooler water.

4.2 Counter-current Steam Flow

The maximum amount of counter current steam flow is limited to the same mass-flow as the equivalent liquid water flow. However, the peak steaming rates have been revised downward to a maximum of [[ ]] [1][4]. Under the conditions of Test 4, no water flow is supplied from the lower tie plate and therefore the most steam flow that can be produced under steady state conditions is equal to the liquid water flow. The steam flow will be represented by an increasing mass flow of air in the tests up to the mass flow of water but limited to [[ ]]. This approach is consistent to the approach taken for the full height bundle tests [2].

Some tests will transition to the simulation of counter-current steam flow. These tests will gradually increase the counter-current flow magnitude marking the evolution of the debris bed as counter-current steam flow is increased up to the test water flow rate or the limit of [[ ]] (whichever is lower).

The air injection temperature will be controlled to near the target test water temperature to within 10°F. Excellent heat-transfer between the air and the water phase will lead to a homogenous temperature within the mixture when each source temperature is controlled adequately.

4.3 Debris Preparation

4.3.1 Fibrous Debris

Fibrous debris will be prepared according to the NEI fibrous debris preparation protocol [9] but then modified further to represent the finer debris that is expected to bypass the suppression pool sump. In particular the generated NEI fiber slurry will be allowed to settle. The water will be poured slowly over a perforated plate with 1/8 in holes. The same pressure washer used in the initial debris preparation will then be used to rinse any fiber caught on the perforated plate through the perforated plate to further reduce any remaining fiber entanglements and also provide additional dilution. The perforated plate matches the maximum hole diameter of the BWR strainer fleet [10] therefore providing a conservatively large debris size distribution. Biasing the debris size distribution to greater sizes is expected to make the test more sensitive to the potential effects of fuel rod surface characteristics. A sample of the prepared debris will be compared to the length distribution obtained in BWROG sponsored bypass testing [10] to demonstrate that the obtained debris distribution is acceptable. Note that a separate ongoing effort will provide additional details on the required debris preparation for full height bundle testing. It is not necessary to follow this specification to achieve the objective of BT2.

4.3.2 Particulate Debris

The particulate debris composition will match representative conditions in the BWROG fleet. The particulate mix will be based on a sludge debris quantity of 765 lbm [11] in the suppression pool and a ZOI particulate quantity of 85 lbm (Assumption b), [12]. Unqualified coatings outside of the ZOI are assumed to fail to a material type similar to the coatings debris within the ZOI (see Assumption a). Sludge debris will be represented by iron oxide debris with a size distribution nominally matching the data provided in the Utility Resolution Guide (URG) [11]. ZOI particulate debris will be represented by jet-pulverized acrylic paint chips with a nominal diameter range of 10-25 µm. The particulate constituents will be mixed dry and then slowly wetted with water producing a uniformly mixed slurry of particulate debris.

4.3.3 Debris slurry

The fiber and particulate mixtures are combined to form one debris addition slurry. Three particulate to fiber (P/F) ratios will be investigated: 1:1, 3:1 and 10:1 (by mass), representing a wide range of possible debris mixtures that could occur post-accident at the fuel assembly. For each P/F ratio, a debris quantity that is sufficient to form a debris bed on the spacer grid must be established. The debris bed formation quantity will be determined without counter-current steam flow. A debris bed is considered to be established when the differential pressure across the spacer grid at the midpoint of flow rates ([[ ]]) reaches 2 in H_2O(re68°F) above the background pressure drop across the spacer grid. The differential pressure rise is set relatively low since the flow rates and associated velocities are very low. A relatively low differential pressure rise therefore is sufficient indication of an established debris bed. Debris quantities will be limited by those expected to bypass the plant strainers on a per fuel bundle basis. However, debris bed development is expected to occur below these debris quantity limits.

The debris slurry concentrations will be kept in the prototypical range and based on the following calculations that tend to bias the concentration towards the higher end. The suppression pool water volume per fuel bundle has been estimated at above 140 ft^3 [13]. The number of fuel bundles in the reactor vessel is above 500. The nominal fibrous debris generated is set to 500 ft^3. The manufactured density of the debris is set to 2.4 lbm/ft^3, consistent with the manufactured density of Nukon [14]. The debris bypass concentration is conservatively set equal to the nominal debris concentration from the above calculations. The resulting fibrous debris concentration entering the reactor vessel according to these inputs is 1.0 g/gallon. The concentration can further be conservatively increased to 1.5 g/gallon. From this concentration, the required water volume can be determined for a range of fibrous debris loads. The particulate debris is added at the required ratio, depending on the test being conducted.

Due to practical limitations, the debris slurry volume is limited to 20 gallons. Based on a prototypical concentration of 1.5 g/gallon, a limit of 30g of fiber can be tested at this concentration. The prepared volume of the debris slurry is diluted to accomplish the target debris concentration. The upper limit of 30g may be above the maximum debris quantity per fuel bundle that can be expected to arrive at the fuel bundle under even the most limiting conditions. If higher debris quantities are to be tested, the debris concentration must be increased. Before increasing the debris concentration, a repeat test must be conducted that demonstrates that increasing the debris concentration does not affect the results. For example, to add 120g of fiber to the test, a test must first be conducted that verifies that a representative debris slurry made from 30g of fiber prepared in 5 gallons produces the same results as a debris slurry made from 30g of fiber prepared in 20 gallons.

The 20 gallon volume of debris slurry is likely above the capacity of the debris introduction region. For cases where additional debris slurry volume beyond the capacity of the debris introduction region must be added, the discharge of the loop is diverted to the water reservoir at the beginning of the test. The debris slurry in the debris introduction region is manually stirred as the remaining debris slurry volume is slowly added to maintain a constant water level in the debris introduction region.

4.4 Fuel Rod Stub Surface Preparation

The surface characteristics of the fuel rod stubs will be changed using two different methods. In addition, clean stainless steel or Zircalloy fuel rod stubs will be used to provide a baseline for performance. The clean baseline fuel rod stub reference surface finish will be smooth. The other two surface preparations used will be as follows:

- Epoxy paint coat of 1/8" NPT stainless steel pipe. The Epoxy will maintain a somewhat smooth surface (although rougher than the baseline) but cause a measurable increase in the diameter.
- Grit paint coat of 1/8" NPT stainless steel pipe. The grit coat will have a very rough surface and exhibit a small increase in diameter as well.

Each of these treatment methods will be characterized using caliper measurements and visual microscopic evaluation. The microscopic evaluation will allow relative quantification of the roughness of the surfaces for evaluation and comparison to possible prototypical conditions.

5.0 Instrumentation

The testing described above will involve a variety of instrumentation. The requirements will be described in the following subsections.

5.1 Flow meters

Flows will be measured with an uncertainty of better than 1.5%, considering the entire measurement train, including contributions from the meter calibration and any associated instruments (e.g. differential pressure cells, absolute pressure cell). The water flow meter will achieve the required accuracy over the required range between [[ ]]. For differential pressure water flow meters Equation 5-1 describes how the flow rate is calculated from the differential pressure measurement and the meter characteristics.

The air flow meter will be able to measure flows between [[ ]][15]. The air flow rate measurement will require an absolute pressure transducer to properly measure the inlet density of the air. The measurement will also require a dedicated temperature probe for the same reason. The verification that a given test setup meets the uncertainty requirements should follow the analysis provided in Reference [15]. The mass flow rate and associated uncertainty requirements are detailed in Equations 5-2 to 5-4 [15]. The same equation may be used to calculate the uncertainty fraction in the water flow rate if the final two terms are dropped.

$$Q = C_d A_t \sqrt{\frac{2\Delta p}{\rho(1-\beta^4)}} \qquad \text{5-1}$$

$$\dot{m} = C_d A_t \sqrt{\frac{2\rho_1 \Delta p}{1-\beta^4}}\, Y \qquad \text{5-2}$$

$$Y^2 = r^{2/\gamma}\left(\frac{\gamma}{\gamma-1}\right)\left[\frac{1-r^{(\gamma-1)/\gamma}}{1-r}\right]\left(\frac{1-\beta^4}{1-\beta^4 r^{2/\gamma}}\right) \qquad \text{5-3}$$

$$\frac{\delta\dot{m}}{\dot{m}} = \sqrt{\left(\frac{\delta C_d}{C_d}\right)^2 + \left(\frac{1}{2}\frac{\delta\Delta p}{\Delta p}\right)^2 + \left(\frac{1}{2}\frac{\delta p}{p}\right)^2 + \left(\frac{1}{2}\frac{\delta T}{T}\right)^2} \qquad \text{5-4}$$

Where:

Q – volume flow rate

$\dot{m}$ – air mass flow rate

C_d – meter discharge coefficient

A_t – throat area

ρ_1 – inlet density

Δp – differential pressure measurement

β – Ratio of throat to inlet diameter

Y – Expansion factor

γ – ratio of specific heats (1.4 for air [15]) r – ratio of throat to inlet pressure

p – absolute inlet pressure

T – air temperature (absolute temperature scale)

δ – uncertainty

5.2 Differential pressure transducers

Differential pressure will be measured at several locations, serving various functions. The following subsections describe the location function and requirements for the instruments.

5.2.1 Level instrumentation

Since some of the debris slurry will be added manually, it is important to track the water level in the debris introduction region to document a consistent addition rate. The level instrumentation will consist of a differential pressure cell where the low port of the cell is open to atmosphere and the high port measures the water level in the debris introduction region. Maintaining the water level consistently within a range of +/- 3 inches will be sufficient. The accuracy requirement on the cell is therefore relatively broad. A differential pressure measurement that is accurate to within 1 inch will allow the requirement to be met, even at 50% void fraction conditions.

Once debris introduction is complete, the variation of level in the debris introduction zone can be indicative of hold-up of air and or water in the region below or above the spacer grid. The level instrumentation should therefore have an appreciable range, greater than 36 inches.

5.2.2 Void fraction measurement

The mean void fraction can be measured by using a differential pressure cell between two ports along the inlet section. Even with air flow, the fluid dynamic pressure drop will be very small but by connecting the DP cell ports with water solid legs to the experiment, the measured differential pressure will be proportional to the void fraction. Under water solid conditions, the DP cell will measure no differential pressure as the water solid high (H) port leg exerts just as much pressure onto the cell as the low pressure port leg (L). Once air begins to flow, the pressure exerted in the test section on the low pressure port leg will decrease because the mean density of the fluid will decrease. This density decrease will manifest itself as an increase in differential pressure. A sufficiently large differential pressure that will allow measurement will be generated when the two ports are separated by approximately 12 inches. The relationship between void fraction and differential pressure is given by Equation 5-5. The equation ignores any contribution from air density which is an appropriate approximation. The measurement is a secondary measurement of void fraction which is primarily based on the ratio of air flow to water flow rate. However, adding a second measurement, above the spacer grid will allow the development of air hold-up below the spacer grid to be diagnosed. Measurement stability will be enhanced by using relatively small diameter pressure port penetrations to the test section which will reject a good portion of the dynamic pressure fluctuations that occur naturally in a bubbly flow. Penetrations with a diameter less than 0.125 inches are recommended. A small downward angle can help ensure that the DP cell lines leaving the test section remain water solid during testing. An angle above 10 degrees is recommended.

$$V_F = \frac{\Delta p}{\rho \cdot g \cdot h} \quad 5\text{-}5$$

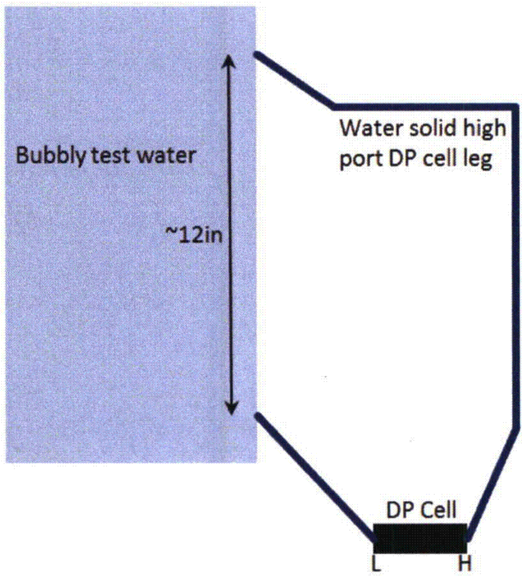

Figure 5-1. DP cell void fraction measurement

The range of the DP cell should exceed 12 inches and the accuracy should be better than 0.125 in H_20 (re68°F).

5.2.3 Spacer grid differential pressure

A key measure of the differences between surface treatments will be the development of spacer grid differential pressure once debris is allowed to interact with the spacer grid. To ensure the greatest sensitivity and still provide adequate range, the spacer grid differential pressure will be measured using two instruments. A low range differential pressure cell with a range of less than 0.5 psid (but greater than 2 in H_20 (re68°F)) will be used to provide real-time electronic measurement. A manometer board will also be connected that will be used to measure differential pressures in excess of 0.5 psid, should they occur. The manometer board measurements will be performed by hand once the differential pressure has exceeded the range of the electronic differential pressure cell. These measurements will still allow for a very good differential pressure measurement accuracy of less than 0.125 inH_2O (~0.0045 psid).

5.2.4 Filter bag differential pressure

The differential pressure across the filter bag will also be monitored during testing since the rise of differential pressure across the filter bag is indicative of the timing and quantity of debris that bypasses the spacer grid. Since the filter bag essentially represents an established fine debris bed, the differential pressure response across the filter bag is expected to be significant. A differential pressure cell with a range of at least 5 psid will be employed. The accuracy of the measurement will be better than 0.05 psid in order to allow sufficient resolution of differential pressures down to 1 psid.

5.3 Absolute pressure transducer

An absolute pressure transducer is required to correctly measure the inlet density to the air flow meter. Since the supply pressure for air is expected to be on the order of 50-60 psig, an absolute pressure sensor with a range of greater than 80 psia is expected to be sufficient. A measurement accuracy of better than 0.3 psia will ensure that the inlet density measurement does not contribute significantly to the air mass-flow measurement uncertainty (see Section 5.1).

5.4 Temperature probe

The test temperature will be monitored on the suction side of the pump. The range of the temperature measurement for BT2 need only encompass the range between 75°F and 85°F. Based on the desire to keep the test temperatures constant within 5°F, a measurement accuracy of 1°F is sufficient.

The air supply temperature is required to determine the air mass flow through the differential air flow meter. The temperature is expected to be in the range between 70°F and 100°F. To ensure the air temperature measurement uncertainty does not affect the flow rate measurement significantly, a measurement uncertainty of 1°F is sufficient.

5.5 Data acquisition board

A data acquisition board will be used to acquire the data generated by the electronic sensors in the test. The key requirements for the data acquisition board are to measure the inputs to an accuracy of better than 0.5mV. Since the envisioned sensors will generate voltages above 5V at full range, the accuracy requirement ensures that the sensor uncertainty will dominate the overall measurement uncertainty. The data acquisition board will need to have the capability to acquire at least seven sensors at the same time. The air flow meter inlet temperature will be measured electronically and in real time. It is not necessary to acquire the test water temperature electronically in real time. The temperature will be noted in the test log at regular intervals throughout testing.

5.6 Scales

Debris weights will be determined to an accuracy of better than 0.3% for weights above 10g, which is expected to encompass all required debris weights.

5.7 Filter bag weight gain

Filter bag weight gain will be determined by measuring the clean weight of the filter bag before use and then measuring the post-test weight of the filter bag. The relative humidity of the measurement environment will be controlled to ensure that the hygroscopic nature of fabric filter bags does not bias the measurement. The weight gain will be determined to an accuracy of 0.05g or 1%, whichever is greater.

5.8 Visual diagnostics

5.8.1 <u>Microscope</u>

A microscope will be used in the characterization of the fuel rod stub surfaces. The microscope measurements will be quantitative via a calibration of the microscope viewing field using a NIST traceable size standard. The size standard will allow the microscope measurement accuracy to be characterized down to 1 µm. Digital photographs of the fuel rod stub surface will be taken and stored as part of the test record.

5.8.2 Debris blockage examination

The spacer grid will be examined photographically after each test. The test assembly, including the spacer grid, fuel rod and water rod stubs will be removed from the test channel in one piece, thereby not disturbing the developed debris bed. The developed debris bed will be photographed with a field of view that includes no more than 4 fuel rod stubs in a single frame using macro-photography. The debris bed examination will therefore remain somewhat subjective but the systematic methods involved are expected to provide further insight into any definitive trends between clean fuel rod stubs and other modified surface fuel rod stub types.

In addition to the described photographic examination, a light transmission photograph will also be taken that will document the degree of blockage of the grid. The post-test light transmission photograph will be compared to a similar photograph pre-test. It is expected that these measurements will provide an additional measurement of debris bed differences between tests. It should be noted that the spacer grid and filter bag differential pressure measurements will be the primary method of comparison between tests. The photographic measurements described here are expected to provide confirmation of the trends identified in the differential pressure measurements.

5.9 Calipers

Calipers will be used to define the mean and variation of the fuel rod stub outside diameter. To achieve the goals of the characterization of both the mean and variation of the fuel rod stub diameter, an accuracy of 0.0005 inches will be sufficient over lengths of up to 1 in. Additionally, lengths of up to 6 in should be able to be measured to within 0.002 in.

6.0 Testing Scope & Limitations

6.1 Scope

6.1.1 Fiber quantity development

One of the fuel rod stub surface preparation methods will be used in determining the fiber quantity required to form a debris bed at each of the particulate to fiber ratios. Fiber quantities will be determined to the nearest 2.5 g that will cause at least a 2 in H_20 (re68°F) differential pressure at a flow rate of [[ ]] (see Section 4.3.3). The initial fiber quantity to be evaluated will be 30 g for the 1:1 P/F ratio. Starting debris quantities for the other P/F ratios will be derived from the 1:1 P/F ratio results, recognizing that higher P/F ratios are generally associated with greater head-loss. If the fiber quantities rise above 30 g, an additional debris concentration test must be conducted to demonstrate that higher debris concentrations do not lead to non-prototypical changes in debris bed development at lower debris quantities (see Section 4.3.3). The debris beds formed in the initial fiber quantity development phase should be photographed but need not be investigated to the full rigor of Section 5.8.2 requirements.

6.1.2 Fuel-rod surface sensitivity

Once the fiber quantity has been established for each P/F ratio, testing for fuel rod stub surface characteristics sensitivity may begin. For each P/F ratio, one additional test is performed using the fuel rod stub surface preparation method with which the fiber quantities were developed. These tests will demonstrate the degree of repeatability in the test. For each of the remaining two surface preparation methods to be evaluated, the tests for only one of the particulate to fiber ratios must be repeated. The test that demonstrates the largest difference from the reference surface preparation method (at the same P/F ratio) will be repeated. Once the test fiber quantities have been established, a total of 3 x 3 + 2 x 1 = 11 tests will therefore be conducted without counter-current steam flow at [[ ]].

Table 6-1. Initial Test Matrix

Test	P/F	Roughness	Note
1	1:1	A	Conducted during Section 6.1.1 testing.
2	3:1	A	
3	10:1	A	
4	1:1	A	Repeats
5	3:1	A	
6	10:1	A	
7	1:1	B	
8	3:1	B	
9	10:1	B	
10	1:1	C	
11	3:1	C	
12	10:1	C	
13	Choose One	C	Repeat
14	Choose One	C	Repeat

The results of the tests are then examined for any trends with fuel rod surface preparation method. If no trends with surface preparation are identified, an additional eight tests are performed according to Table 6-2. If a trend with surface preparation is already evident after the conducted tests, no further testing without counter-current steam flow simulation is required.

Table 6-2 presents a four factor resolution IV Design of Experiments test sequence that includes debris concentration. Debris concentration is added as a variable since these eight tests are run to determine main effects. Reducing the number of factors by one still requires eight runs since a four run DOE with three factors would confound a potentially important interaction (P/F ratio and flow rate) with the most important main effect (surface preparation) [16].

Table 6-2. Follow-up surface sensitivity testing

Surface preparation	Flow (gpm)	P/F ratio	Debris Concentration (g-fiber / gallon)
Clean fuel rod	[[ ]]	10:1	2
Grit paint	[[ ]]	10:1	4
Clean fuel rod	[[ ]]	10:1	4
Grit paint	[[ ]]	10:1	2
Clean fuel rod	[[ ]]	1:1	4
Grit paint	[[ ]]	1:1	2
Clean fuel rod	[[ ]]	1:1	2
Grit paint	[[ ]]	1:1	4

The purpose of the above test series is to ensure that a sufficient area of the parameter space has been investigated to bring out any potential effects of surface characteristics on the spacer grid debris bed formation in the absence of counter-current steam flow simulation. It is not aimed at quantifying the relationship between surface characteristics and spacer grid debris bed formation.

6.1.3 Counter-current steam flow simulation

Counter-current steam flow simulation will be investigated for two fuel rod surface preparation methods. If no sensitivity to fuel rod surface conditions was measured during Section 6.1.2 testing, the roughest fuel rod surface preparation method (grit paint) will be employed in counter-current steam flow simulation. If a sensitivity was determined, the most conservative (highest head-loss) fuel rod surface preparation method will be tested with counter-current steam. The clean fuel rod stubs will represent the reference surface condition.

For each particulate to fiber ratio, the debris bed will be allowed to develop as in Section 6.1.2 but at [[ ]], before gradually adding counter current air injection below the spacer grid. A higher flow rate is employed since debris bed resilience differences are expected to be more likely when the debris bed formation flow rate is at its highest.

Counter-current air flow is increased until a re-suspension of the debris bed can be visually observed through an increase in the turbidity of the water. Once the debris bed has been disturbed, counter-current air flow is once again reduced and turned off. Head-loss across the debris bed is allowed to re-develop to steady state conditions. If the debris-bed head-loss has reduced to below 50% of the original head-loss, the counter-current steam flow rate that allows blockage removal has been determined as the peak air flow employed during the transient. If the debris bed head-loss was not reduced to below 50% of the original head-loss, an additional counter-current air flow excursion is implemented to a rate that is 20% greater than the first flow rate. Additional increases in counter-current air flow will be implemented until either the mass-flow rate limit of air injection is reached or the steady spacer grid head-loss is reduced to below 50% of its initial value.

The air flow rate at which a 50% reduction from the initial head-loss is achieved will be compared between clean fuel rod stubs and the chosen rougher counterpart. Fuel rod surface conditions affect the resilience of the spacer grid debris bed only if the measured air flow rates for the clean fuel rod stubs can be shown to be lower than the flow rates for the rougher counterpart with a statistical certainty of greater than 85%.

6.2 Limitations

6.2.1 Tests without counter-current steam flow simulation

Tests are limited in water flow rate to the range between [[ ]]. Filter bag differential pressures must be limited to less than the range of the differential pressure cell measuring the pressure drop. The debris slurry volume is limited to 20 gallons which limits the amount of debris that can be added at a given concentration.

6.2.2 Tests with counter-current steam flow simulation

In addition to the limitations discussed in Section 6.2.1, the steam flow simulation measurements are limited in the amount of air flow that can be added to [[ ]] or the equivalent mass flow rate of water of the given test (whichever is lower).

7.0 Test Procedure

Testing will proceed using the following general steps, which will be refined in the development of the detailed test procedure:

- Debris slurry is prepared.
- Test loop is verified to be clean.
- Spacer grid has been qualified for use.
- The required fuel rod stubs have been installed in the spacer grid.
- The spacer grid assembly with the fuel rod stubs is installed in the test rig.
- The test setup is documented photographically.
- A clean pre-weighed filter bag has been installed in the filter bag cartridge housing.
- The loop is filled with water at the target test temperature.
- With the water level at the target level but the debris gate still open, the loop pump is started with the recirculation line aligned to the debris introduction section.
- The loop pump speed and throttle valve are adjusted to achieve the target flow rate for the test.
- The recirculation line is aligned to the fill tank.
- The fill tank branch throttle valve is adjusted to maintain the target flow rate
- The flow remains aligned to the fill tank to drain the debris inlet section.
- The pump discharge isolation valve is closed.
- The debris gate is closed and the fill pump is aligned to hold the debris gate closed.
- The data acquisition system is set up to begin collecting data.
- The debris slurry is added to fill the debris introduction section. If the debris slurry volume does not fit into the debris introduction section in its entirety, the recirculation line remains aligned back to the supply water tank, otherwise, the recirculation line is aligned to the debris introduction zone.
- The fill pump discharge valve is closed, the loop pump isolation valve is opened and the debris introduction gate is opened.

- The flow rate is monitored throughout the test and adjusted as needed.
- The test is continued until the water has cleared and the differential pressure across the spacer grid and filter bag assembly has stabilized.
- For tests that simulate counter-flow steam, air flow is added after the head-loss has been stabilized by slowly opening the air throttle valve.
- During air-flow injection, the air flow rate and air flow supply pressure are monitored carefully. The loop flow rate is also likely to require adjustment when air-flow is being introduced to the test. Bulking of the water due to the presence of air may require recirculation flow alignment to the tank and subsequent refilling of the debris introduction section with clean water when air flow is secured.
- When airflow is secured, the debris bed is monitored for a new equilibrium head-loss steady state.
- Air flow cycles are repeated as needed.

8.0 Test Acceptance and Termination Criteria

8.1 Test termination criteria

The test is terminated when the head-loss across the spacer grid and the filter bag have stabilized (<1% change in 30 minutes) and any air flow excursions have been completed successfully.

8.2 Test acceptance criteria

The flow rate has to be maintained within +/-5% during the entire test. The differential pressure across the filter bag must remain within the range of the differential pressure transducer used to monitor the pressure differential. The test temperature must remain within 5°F of the target of 80°F for the entire test. Air flow rates must remain below the equivalent mass-flow rate of water in the test or [[ ]] (whichever is less). The air injection temperature must remain within 10°F of the test temperature. The test termination criteria must be met successfully. The spacer grid must meet the inspection criteria before each test.

9.0 Procedure List

Table 9-1 lists the project specific procedures that will be written based on the present test plan and the generic Alden QAP procedures that will be specifically invoked to support the execution of testing and the evaluation of test results.

Table 9-1. Procedures supporting testing

Procedure number	Title
1140BWRBT-451	Facility inspection
1140BWRBT-452	Test procedure
1140BWRBT-453	Debris preparation procedure
1140BWRBT-454	Spacer grid debris bed evaluation procedure
1140BWRBT-401	Spacer grid handling and verification procedure
1140BWRBT-402	Fuel rod stub characterization procedure
QP-3201	DP cell check procedure
QP-3202	Temperature probe check procedure
QP-3203	Filter bag weighing procedure
QP-3205	Debris handling
QP-3208	Handling and storage of samples and filters
QP-3214	Filter qualification

10.0 References

[1] 1120BWRFA-201, "BWR Fuels Hydraulic Test Program – Project Plan".
[2] 1120BWRFA-106-00, BWROG-12016, "Submittal of Batch 2 Responses to RAIs Associated with Boiling Water Reactor Owners' Group (BWROG) Licensing Topical Report NEDC-33608P, "Boiling Water Reactor Emergency Core Cooling Suction Strainer In-Vessel Downstream Effects".
[3] 1120BWRFA-105-00, BWROG-12005, "Submittal of Batch 1 Responses to RAIs Associated with Boiling Water Reactor Owners' Group (BWROG) Licensing Topical Report NEDC-33608P, "Boiling Water Reactor Emergency Core Cooling Suction Strainer In-Vessel Downstream Effects"
[4] 1120BWRFA-141-00, "BWROG-13032, Submittal of Responses to Supplemental RAIs Associated with Boiling Water Reactor Owners Group (BWROG) Licensing Topical Report NEDC-33608-P, 'Boiling Water Reactor Emergency Core Cooling Suction Strainer In-Vessel Downstream Effects'", 06/28/2013.
[5] 1120BWRFA-107-00 Item 2, "GNF 2 Design Basis", DB-0011.03 Rev. 8, 2013*
[6] 1120BWRFA-109-00 Item 5, "Flow rate and/or driving head ranges for each of the tests".
[7] 1120BWRFA-145-00, "Spacer grid drawings", 107E1175 Rev 9, 107E117 Rev. 11, 107E1177 Rev. 9, 107E1178 Rev. 5.
[8] 1120BWRFA-137-00, Item 3, "Spacer grid locations", 105E3924 Rev. 5.
[9] REF-116-01, "NEI fibrous debris preparation protocol", Rev. 1, January 2012.
[10] BWROG-14015 – ECCS Suction Strainer Bypass Test Report.
[11] "Utility Resolution Guide for ECCS Suction Strainer Blockage", NEDO-32686-A, Adams Accession Number: ML092530482, 1998.
[12] BWROG-ECCS-TP-8-3 "Coatings ZOI".
[13] BWRFA-149-00, "Miscellaneous design inputs"
[14] "Pressurized Water Reactor Sump Performance Evaluation Methodology", Revision 0, ML050550138, December 2004.
[15] 1120BWRFA-302, "BWR Fuels Test Loop Design".
[16] D.C. Montgomery, "Design and Analysis of Experiments", 2nd ed., Wiley, 1984.

*The GNF 2 design basis document compares the fuel design to the reference fuel design for the full height bundle testing GE-14. The document therefore provides many useful technical inputs for GE-14 type fuel.

Appendix A

Items for Inspection / Control

- Experimental set-up must be verified to be functionally equivalent to Figure 3-1.
- Debris introduction region requirements:
  - Debris must not transport to spacer grid immediately upon introduction.
  - The added debris must be kept suspended after addition to the loop.
  - The debris introduction system must demonstrate minimal debris retention.
  - The start of debris flow must be able to be coordinated with the start of flow through the spacer grid.
  - The debris introduction region must have a minimum volume of 5 gallons.
  - Debris introduction hardware must withstand temperatures up to boiling.
  - Hardware installed in flow must have one dimension less than 2in.
- Inlet region:
  - Cross-section of 5.0625 in (+/- 0.0625 in).
  - If debris introduction region is round, first transition to square cross-section that encompasses round section.
  - Contract to square target cross-section at an angle shallower than 20 degrees.
  - 15-18in of straight flow development length.
  - Hardware installed in flow must have one dimension less than 2 in.
- Spacer grid installation:
  - Fuel rod stub length above spacer grid is at least [[ ]].
  - Fuel rod stub length below spacer grid is at least [[ ]].
  - Roughened fuel rod stubs to be made in 2 parts.
  - No flow through fuel rod stubs, no air release (verify with flow visualization).
  - Verify the following before first test and after all tests:
    - Photograph selected fuel rod passages to document clean condition
    - Verify three radial points of contact for each fuel rod stub using clean fuel rod.
    - Compare square dimensions of spacer to requirements and past measurements.
  - Axial motion only for assembly of fuel rod stubs.
  - Simulated water rod outer diameter [[ ]] (+/- 0.03 in).
  - Tabs on water rods sufficient to prevent free movement.
  - Water rods will extend minimum [[ ]] upstream and [[ ]] downstream of the spacer grid.
  - No flow through water rods.
  - No debris hold-up on water rod stub or fuel rod stub tips.
  - Dominant path of flow is through spacer grid, no flow acceleration into clearance around spacer grid. Verify using flow visualization.
  - Dye injection ports near spacer grid surface and within clearances around spacer grid.
- Air introduction:
  - Relatively uniform air distribution at the bottom of the spacer grid. No slug flow. Document uniformity using video from all four sides.
  - Air injection not in counter-current direction.
  - If air introduction manifold obstructs flow, removal must be possible to assess debris hold-up.
  - At least 6 in of straight section below air introduction.

  - No air transport in downstream direction.
- Outlet section:
  - Introduces bypass flow with minimum of 10 gpm
  - Pipe connection diameter below 2 in.
  - Contraction angle no faster than 20 degrees.
  - No settling on surfaces.
  - No flow pattern influence at air introduction location.
  - Return flow rate controlled by throttle valve downstream of pump.
  - Must be able to switch from water discharge to debris introduction region recirculation without flow interruption.
- Debris preparation:
  - NEI debris preparation filtered through 1/8 in perforated plate.
  - Sample comparison to BWR bypass report length distribution.
  - Fiber and particulate are mixed before introduction.
- Debris bed development requires head-loss of 2 in H_20 (re68°F)
- Standard debris concentration preparation is 1.5g / gallon.
- Fuel rod surface roughness requires microscopic evaluation as well as average diameter measurement.
- Instrumentation:
  - Flow meter measures flow to better than 1.5% of reading for entire measurement train.
  - Flow meter range encompasses [[ ]].
  - Air flow meter range encompasses [[ ]]
  - Level measurement DP cell: range > 36 inches, accuracy better than 1 in.
  - Void fraction measurement:
    - Taps separated by 12 inches
    - Maximum tap diameter of 0.125 inches
    - Range > 12 in H_20 (re68°F), accuracy better than 0.125 in H_20 (re68°F)
  - Spacer grid differential pressure:
    - 0.5 psid > Range > 2 in H_20 (re68°F), accuracy better than 0.125 in H_20 (re68°F).
  - Filter bag differential pressure:
    - Range > 5 psid, accuracy better than 0.05 psid.
  - Absolute pressure transducer:
    - Range > 80 psia, accuracy better than 0.3 psia.
  - Temperature probe:
    - Range encompasses 75°F- 85°F, accuracy better than 1°F.
  - Data acquisition board / system:
    - Accuracy of better than 0.5mV for 0-5V, 0-10V ranges.
    - Ability to measure air-flow inlet temperature in real time.
    - Ability to measure at least 7 inputs at the same time.
  - Scales:
    - Weights above 10g must be accurate to better than 0.3%.
  - Filter bag weight gain:
    - Weight gain will be determined to within 0.05g or 1%, whichever is greater.
  - Microscope:
    - Requires NIST traceable size standard, allowing size characterization down to 1 μm.

- Ability to take digital photographs of surface.
- Debris blockage examination:
    - Requires macro photography of no more than 4 fuel rod stubs in a single frame.
    - Light source and gray-scale camera required for light transmission measurements.
- Calipers: Accuracy and resolution of better than 0.0005 inches within 1 in, 0.002 in within 6 in.

ENCLOSURE 3

Affidavit, dated September 2014

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, Peter M. Yandow, state as follows:

(1) I am the Vice President, NPP/Services Licensing, Regulatory Affairs, GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Alden report 1140BWRBT-302-01-P, "BT2 – Fuel Rod Surface Effects Test Plan – Revision 01," Revision 01, dated September 2014. GEH proprietary information in 1140BWRBT-302-01-P is identified by a dotted underline inside double square brackets. [[This sentence is an example.{3}]]. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the *Freedom of Information Act* ("FOIA"), 5 U.S.C. §552(b)(4), and the *Trade Secrets Act*, 18 U.S.C. §1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies under the narrower definition of trade secret, within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F.2d 871 (D.C. Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F.2d 1280 (D.C. Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without a license from GEH constitutes a competitive economic advantage over other companies;

b. Information that, if used by a competitor, would reduce its expenditure of resources or improve its competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information that reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information that discloses trade secret or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions for proprietary or confidentiality agreements or both that provide for maintaining the information in confidence. The initial designation of this information as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GEH.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary and/or confidentiality agreements.

(8) The information identified in paragraph (2) is classified as proprietary because it contains detailed methods, results, and conclusions regarding supporting evaluations of the effects on nuclear fuel performance of containment debris that bypasses the ECCS suction strainers for a GEH BWR. The analysis utilized analytical models and methods, including computer codes, which GEH has developed, obtained NRC approval of, and applied to perform evaluations of containment debris effects on the nuclear fuel for a GEH BWR.

The development of the evaluation processes along with the interpretation and application of the analytical results is derived from the extensive experience and information databases that constitute major GEH assets.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH. The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial. GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 29th day of September 2014.

Peter M. Yandow

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